Gamma Ray Bursts statistical properties and limitations on the physical model

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Abstract

The present common view about GRB origin is related to cosmology. There are two evidences in favour of this interpretation. The first is connected with statistics, the second is based on measurements of the redshifts in the GRB optical afterglows. Red shifts in optical afterglows had been observed only in long GRB. Statistical errors, and possibility of galactic origin of short GRB is discussed; their connection with Soft Gamma Repeaters (SGR) is analyzed.

1 Introduction

Cosmological origin of GRB had been first suggested in [Prilutsky and Usov(1975)] soon after their discovery. The present model of cosmological GRB based on production of gamma quanta from neutrino collisions $\nu + \bar{\nu} \to e^+ + e^-$ was first considered in [Berezinsky and Prilutsky(1987)]. The efficiency of transformation of the neutrino flux $W_{\nu\bar{\nu}} \sim 6 \times 10^{53}$ ergs into gamma quanta was estimated as $\sim 6 \times 10^{-6}$, giving a pulse $W_\gamma \sim 3 \times 10^{48}$ ergs. It could explain the cosmological GRB only at rather narrow pulse beam. In the giant GRB 990123 the isotropic energy production is very large [Kulkarni et al.(1999)] in gamma $W_\gamma \approx 2.3 \times 10^{54}$ ergs, and in optics $W_{\mathbf{opt}} \sim 10^{51}$ ergs. Simultaneous strong beaming in gamma and optical bands is rather unplausible. Strong beaming would modify the observed smooth optical light curve in presence of a source rotation. Some problems in GRB interpretation and modelling are discussed.

2 Statistics and restrictions to the model

BATSE data start to deviate from the uniform distribution with 3/2 slope at rather large fluences, for which KONUS data are well defined. Analysis of KONUS data had been done in [Higdon and Schmidt(1990)]. Taking into account selection effects, the resulting value $V/V_{max} = 0.45 \pm 0.03$ was obtained. KONUS data had been obtained in conditions of constant background. Similar analysis [Schmidt(1999)] of BATSE data, obtained in conditions of substantially

1

variable background, gave resulting $V/V_{max} = 0.334 \pm 0.008$. These two results seems to be in contradiction, because KONUS sensitivity was only 3 times less than that of BATSE, where deviations from the uniform distribution $V/V_{max} = 0.5$ in BATSE data are still rather large [Fishman and Meegan(1995)].

In presence of a threshold deviations of V/V_{max} from its uniform Euclidean value 0.5 may be connected with the errors in determination of the burst peak luminosity or total fluence [Bisnovatyi-Kogan(1997)]. Such errors may be connected with spectral differences, variable sensitivity of detectors for bursts coming from different directions, variable background. All these reasons lead to underestimation of the burst luminosity, and decrease the slope of the curve $\log N(\log S)$. There is no angular correlation between GRB and sample of any other objects in the universe.

From the energy conservation law it follows $W < M c^2$, where M is a mass of the source. A proper account of physical laws put much stronger restrictions to the energy output. Calculations of ns-ns collisions gave energy output in (X, γ) region not exceeding 10^{50} ergs [Ruffert and Janka(1998)], and similar results characterize ns-bh collision [Ruffert and Janka(1999)]. Magnetorotational explosion does not give larger energy output in (X, γ) region, transforming about 5% of the rotational energy into a kinetic one [Ardeljan et al.(2000)]. The problems with vaguely defined "hypernova" model had been discussed in [Blinnikov and Postnov(1998)].

The largest γ-ray production efficiency, close to $100\% M c^2$ may be expected, if GRB originate from matter-antimatter star collisions. That arises a problem of antistar creation in the early universe.

Simultaneous γ, X and optical observations in GRB, accompanied by spectral and polarization experiments are very important. Search of hard X-ray lines and of annihilation 0.511 keV, line declared by KONUS, remain to be a puzzle which should be solved. Cosmological GRB explosion in a dense molecular cloud would lead to a specific optical light curve [Bisnovatyi-Kogan and Timokhin(1997)], which discovery would reveal conditions in the region of cosmological GRB explosion. Study of hard γ afterglow, similar to the one observed by EGRET [Schneid et al.(1992)] is expected in a near future.

3   Short GRB and SGR

All afterglows had been measured only for long bursts. It cannot be excluded that short bursts could have another, may be Galactic origin. There is also a possibility, that short bursts are connected with a giant bursts observed in 3 soft gamma repeaters (from 4 known). At larger distances only giant bursts, appeared as short GRB could be observed. If we accept the present interpretation of SRG, as galactic and LMC sources at distances 10-50 kpc, than only giant bursts should be visible in the nearest galaxies as weak (about few 10^{-7}) short GRB. Taking into account that Andromeda is ~ 4 times more massive than our Galaxy [Vorontsov-Velyaminov(1972)], we should expect [Bisnovatyi-Kogan(1999)] to see about 10 short GRB in its direction during the

observation time, while no one was yet observed. Another large galaxy in the local group of galaxies Maffei IC 1805 is also more massive than the Galaxy, and short GRB from it are also expected.

Presently SRG are interpreted as young neutron stars with very strong magnetic field - "magnetars" [Duncan and Thompson(1992)]. The estimation of the distance and, consequently, the luminosity is based on SGR identification with supernovae remnants (SNR), leading to large energy losses. This interpretation has several theoretical objections [Bisnovatyi-Kogan(1999)].

1. Hard gamma pulsars observed in 3 SGR have luminosities strongly exceeding the critical Eddington luminosity. At such luminosity a strong mass loss should smear out the pulses.

2. Rotational energy losses estimated from the period increase rate are much smaller than the observed gamma and X-ray luminosity even in a quiescent state. In the magnetar model the energy comes from the annihilation of magnetic field. Such annihilation should be accompanied by creation of energetic electrons and radio-emission. The radio-emission of SGR is very weak, its discovery is very difficult, and still not firmly established.

3. Giant bursts observed in 3 SGR at present interpretation are accompanies by a huge energy production, part of which should go into particle acceleration and kinetic energy outbursts. It should influence the near-by SNR, and produce a visible changes in radio and optics, similar to those produced by pulsar glitches in the Crab nebula, when much smaller amount of energy is released. No such changes had been reported up to now, probably because they have not been present there.

Another interpretation of SGR, free of these contradictions needs a smaller distance to SGR, what is possible if the connection with SNR would not be confirmed. Note, that all SGR are situated at the very edge, or even outside of the SNR envelope, requiring very high 1000-3000 km/s speed of the neutron star. Refusing this connection and suggesting $\sim 10 - 30$ times smaller distance to SGR would remove the upper objections. The even smaller distances are less probable, because most SGR are situated in the galactic disk, and so should be situated at distances larger than this disk thickness. Existence of one SGR outside the galactic disk direction could indicate to its big age during which it could leave the galactic disk. Discovery of big population of neutron stars in the globular clusters and in the galactic bulge, as recycled pulsars, indicate to existence of neutron stars in the whole volume of the Galaxy.

4   Acknowledgments

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